

What we claim is,

1. An on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode comprising:
 - a p-GaAs single crystal substrate having a top surface and a bottom surface;
 - a p-(ZnSe/ZnTe)^m (m: integer denoting a number of pair layers) superlattice which is
 - 5 made by piling p-ZnSe thin films and p-ZnTe thin films reciprocally for changing bandgaps stepwise and is epitaxially grown directly on the top surface of the p-GaAs substrate;
 - a p- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ ($0 \leq x \leq 0.8$, $0 \leq y \leq 0.8$) layer epitaxially grown on the p-(ZnSe/ZnTe)^m superlattice or via a p-ZnSe buffer layer upon the p-(ZnSe/ZnTe)^m superlattice;
 - an i- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ ($0 \leq x \leq 0.8$, $0 \leq y \leq 0.8$) layer epitaxially grown on the p- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer;
 - 10 a n- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ ($0 \leq x \leq 0.8$, $0 \leq y \leq 0.8$) layer epitaxially grown on the i- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer;
 - a metallic n-electrode which is formed upon a part of the n- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer and has a top aperture for allowing incidence light to enter; and
 - 15 a metallic p-electrode formed on the bottom surface of the p-GaAs substrate.
2. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein a p-ZnSe buffer layer is interposed between the p-(ZnSe/ZnTe)^m superlattice and the p- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer.
3. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 2,
- 20 wherein the i- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer has an impurity concentration less than 10^{16} cm^{-3} .
4. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein the n- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer has a bandgap E_n which is equal to or higher than a bandgap E_i of the i- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer ($E_n \geq E_i$).
5. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 4,
- 25 wherein the i- $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer is an i-ZnS_ySe_{1-y} layer including no Mg (x=0) and the n-

$\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer is either an $n\text{-Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer including Mg ($x \neq 0$) or an $n\text{-ZnS}_y\text{Se}_{1-y}$ layer including no Mg ($x=0$).

6. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 4, wherein the $i\text{-Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer is an $i\text{-ZnSe}$ layer including neither Mg nor S ($x=0, y=0$) and the $n\text{-Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer is either an $n\text{-ZnS}_y\text{Se}_{1-y}$ layer including no Mg ($x=0, y \neq 0$) or an $n\text{-ZnSe}$ layer including neither Mg nor S ($x=0, y=0$).

7. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein the top aperture on the $n\text{-Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer which receives incidence light is coated with a mask made of Al_2O_3 , SiO_2 , TiO_2 , La_2O_3 or MgF_2 for antireflection and protection.

8. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein external quantum efficiency is more than 30 % for light wavelengths between 300nm and 450nm.

9. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein external quantum efficiency is more than 40 % for a light wavelength of 400nm.

10. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ pin photodiode according to claim 1, wherein a dark current is less than 10^{-9} A/cm^2 under a reverse bias between 0 V and -20 V.

11. An on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ avalanche photodiode for inducing avalanche amplification by a strong electric field formed by applying a reverse bias below a breakdown voltage, comprising:

a p-GaAs single crystal substrate having a top surface and a bottom surface;

a $p\text{-(ZnSe/ZnTe)}^m$ (m : integer denoting a number of pair layers) superlattice which is made by piling p-ZnSe thin films and p-ZnTe thin films reciprocally for changing bandgaps stepwise and is epitaxially grown on the top surface of the p-GaAs substrate;

a $p\text{-Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ ($0 \leq x \leq 0.8, 0 \leq y \leq 0.8$) layer epitaxially grown on the p-

- (ZnSe/ZnTe)^m superlattice or via a p-ZnSe buffer layer upon the p-(ZnSe/ZnTe)^m superlattice;
 a lower-doped n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} (0 ≤ x ≤ 0.8, 0 ≤ y ≤ 0.8) layer epitaxially grown on
 the p-Zn_{1-x}Mg_xS_ySe_{1-y} layer;
 a higher-doped n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} (0 ≤ x ≤ 0.8, 0 ≤ y ≤ 0.8) layer epitaxially grown on
 5 the lower-doped n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} layer;
 a metallic n-electrode which is formed upon a part of the higher-doped n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} layer and has a top aperture for allowing incidence light to enter; and
 a metallic p-electrode formed on the bottom surface of the p-GaAs substrate.
12. The on-p-GaAs substrate Zn_{1-x}Mg_xS_ySe_{1-y} avalanche photodiode according to claim 11,
 10 wherein a p-ZnSe buffer layer is interposed between the p-(ZnSe/ZnTe)^m superlattice and the p-Zn_{1-x}Mg_xS_ySe_{1-y} layer.
13. The on-p-GaAs substrate Zn_{1-x}Mg_xS_ySe_{1-y} avalanche photodiode according to claim 11,
 wherein an i-Zn_{1-x}Mg_xS_ySe_{1-y} (0 ≤ x ≤ 0.8, 0 ≤ y ≤ 0.8) layer is interposed between the p-Zn_{1-x}Mg_xS_ySe_{1-y} layer and the n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} layer.
- 15 14. The on-p-GaAs substrate Zn_{1-x}Mg_xS_ySe_{1-y} avalanche photodiode according to claim 11,
 wherein the n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} layer has a bandgap E_n⁺ which is equal to or higher than a
 bandgap E_n⁻ of the n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} layer (E_n⁺ ≥ E_n⁻).
15. The on-p-GaAs substrate Zn_{1-x}Mg_xS_ySe_{1-y} avalanche photodiode according to claim 14,
 wherein the n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} layer is an n⁻-ZnS_ySe_{1-y} layer including no Mg (x=0) and the
 20 n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} layer is either an n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} layer including Mg (x ≠ 0) or an n⁺-
 ZnS_ySe_{1-y} layer including no Mg (x=0).
16. The on-p-GaAs substrate Zn_{1-x}Mg_xS_ySe_{1-y} avalanche photodiode according to claim 14,
 wherein the n⁻-Zn_{1-x}Mg_xS_ySe_{1-y} layer is an n⁻-ZnSe layer including neither Mg nor S (x=0,
 y=0) and the n⁺-Zn_{1-x}Mg_xS_ySe_{1-y} layer is either an n⁺-ZnS_ySe_{1-y} layer including no Mg (x=0, y
 25 ≠ 0) or an n⁺-ZnSe layer including neither Mg nor S (x=0, y=0).

17. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ avalanche photodiode according to claim 11, wherein the top aperture on the n^+ - $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ layer which receives incidence light is coated with a mask made of Al_2O_3 , SiO_2 , TiO_2 , La_2O_3 or MgF_2 for antireflection and protection.
- 5 18. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ avalanche photodiode according to claim 11, wherein external quantum efficiency is more than 100 % for light wavelengths between 300nm and 450nm.
19. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ avalanche photodiode according to claim 11, wherein external quantum efficiency is more than 200 % for a light wavelength of 400nm.
- 10 20. The on-p-GaAs substrate $\text{Zn}_{1-x}\text{Mg}_x\text{S}_y\text{Se}_{1-y}$ avalanche photodiode according to claim 11, wherein external quantum efficiency is enhanced by a spin-orbit interaction at a wavelength of 395nm and sensitivity is nearly flat from 350nm to 430nm.